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Small Mammal Use of Hybrid Poplar Plantations Relative to Stand Age

Abstract

We studied small mammal use of a 9,300-ha complex of hybrid poplar plantations in northeastern Oregon from spring 1997 through winter 1999. Small mammals were surveyed in each of six plantation age classes four times per yr. A total of six rodent and one insectivore species were captured during the study. The three most common species, in declining order of abundance, were deer mouse, Great Basin pocket mouse, and house mouse. Small mammal abundance and species richness were greatest in 1- to 3-yr-old plantations and lowest in 4- to 6-yr-old plantations. Our study suggests that 1- to 3-yr-old hybrid poplar plantations provide suitable habitat for certain small mammals in this region, probably due to abundant understory vegetation. Once plantations reach 4 yr, canopy closure results in a relatively impoverished understory plant community, supporting fewer small mammal species at a lower abundance. Creating habitat heterogeneity by maintaining a diversity of plantation ages within the complex may enhance small mammal species diversity across these landscapes.

Introduction

The establishment of large, hybrid poplar (*Populus* spp.) plantations in North America is becoming increasingly popular with the forest products industry because of the ability of these fast-growing trees to produce abundant wood fiber in a short period of time. In the past 15 yr, over 28,000 ha of hybrid poplar plantations have been established in the Pacific Northwest to produce fiber for both paper and dimensional lumber products (Heilman et al. 1995). In addition to economic benefits, these plantations may provide environmental benefits such as erosion control and carbon sequestration (Paine et al. 1996, Isebrands 2000).

Little is known about the influence of these plantations on small mammal communities. Published studies of small mammal use of hybrid poplar plantations are few and relatively recent, and have taken place primarily in the Midwest (Christian et al. 1997, Christian et al. 1998). Furthermore, these studies primarily document wildlife use of plantations in comparison to surrounding land uses, rather than the effects of stand variables (e.g., stand age) on small mammal populations (Christian et al. 1997, 1998). Because of differences in understory plant cover that exist among different ages of hybrid poplar plantations in northeast Oregon, small mammal assemblages in different age classes may vary. In addition, the conversion of agriculture land and native habitat to plantations may affect both native and non-native fauna by introducing exotic flora (Edge 2001, Witmer and Lewis 2001).

The current interest in hybrid poplar plantations, and the large potential land base available for plantations in North America (Graham 1994) necessitates an understanding of how small mammals use these plantations, because small mammals play an important role in ecological processes, including nutrient cycling, seed dispersal, herbivory, and predator-prey dynamics (Chew 1976, French et al. 1976, Potter 1976). The purpose of this study was to document small mammal use of hybrid poplar plantations in northeast Oregon. In addition, we hypothesized that small mammal relative abundance, species composition, and species richness would vary by plantation age.

Study Area

The study was conducted on a 9,300-ha complex of hybrid poplar plantations in the Columbia River Basin, Morrow County, Oregon. The natural vegetation in this region is steppe and shrub-steppe (Franklin and Dyrness 1988), and soil types are sandy and sandy loam. Topography varies from flat to slightly undulating with elevations ranging from 150 to 250 m. Annual precipitation averages 22 cm (Ruffner 1978), most of which falls in late winter and early spring.

Drip-irrigated plantations were first established in 1992, primarily on former agricultural crop-

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lands irrigated by center-pivot systems. However, < 2 ha tracts of fallow vegetation were also converted to plantations when these tracts were adjacent to converted croplands. Plantations representing six age classes of trees (1- to 6-yr-old) were available for study. These variously aged plantations differed in both tree height and understory composition. On average, hybrid poplars in these plantations grew 3-5 m per yr. During the first 2-3 yr of growth, understory vegetation was often dense (> 90% cover). Common plant species present included the native horseweed (*Conyza canadensis*) and redroot pigweed (*Amaranthus palmeri*), and the naturalized Russian thistle (*Salsola kali*), tumble mustard (*Sisymbrium altissimum*), and cheatgrass (*Bromus tectorum*). Each plantation was sprayed with an herbicide-mixture of glyphosate and 2,4-D, and cultivated once during yr 1 and 2. However, most competing plants quickly recolonized given the favorable growing conditions. Complete canopy closure occurred following yr 3. At this point the understory became nearly devoid of live plants (< 5% cover) and was dominated by organic material primarily composed of leaf litter.

Methods

Three plantations in each of six age classes (1-, 2-, 3-, 4-, 5-, and 6-yr-old) were randomly selected from 229 available plantations to sample small mammal populations. Plantations studied ranged from 55 to 100 ha and all were planted during the first two weeks of April of each yr. Relative abundance and species composition of small mammals in each of the six plantation age classes were estimated by trapping with Sherman live traps (8 x 8 x 23 cm). A trapping grid of 49 traps (7 x 7 grid, 10-m spacing) was established at the center of each plantation. Pilot studies indicated that the appearance of new individuals and species dropped off markedly after four trap nights. Consequently, each replicate plantation was trapped for a period of four consecutive nights during each season (April-May 1997, July-August 1997, October-November 1997, January-February 1998, April-May 1998, July-August 1998, October-November 1998, and January-February 1999). Traps were baited with crimped oats and supplied with polyester batting for insulation. Traps were opened in the afternoon, checked in the morning, and closed during the day to reduce capture mortality. Each individual captured was identified to species, marked with ear tags or toe clipping, weighed, evaluated for breeding condition, and released at the capture site. Subsequent recaptures were not included in the analyses. Relative abundance was estimated as number of individuals captured per 100 trap nights. Mark-recapture analyses were not used because density estimates were not considered necessary to test the stated hypothesis. In addition, low capture rates encountered in some of the plantations would have produced unreliable density estimates using mark-recapture models (White et al. 1982).

Differences in combined relative abundance and species richness of small mammals among different plantation age classes were analyzed for each season using a one-way ANOVA, analyzed by the PROC MIXED procedure in SAS (Littell et al. 1996, SAS Institute Inc. 1996). A Fisher's protected LSD was used to isolate differences in means among age classes. Two-way ANOVA was used to analyze interactions between individual species and plantation age. Only the three most abundant small mammal species had sufficient capture data to provide meaningful individual analyses using the ANOVA procedure. Therefore, data from the four least abundant species were analyzed by the ANOVA procedures only as they could be pooled for overall small mammal abundance and species richness estimates. Differences were considered significantly different at $P = 0.05$.

Results

We captured 1,588 individuals of six rodent and one insectivore species during 28,224 trap nights over the eight trapping periods (Tables 1, 2). Captures included 1,230 (77.5%) deer mice (*Peromyscus maniculatus*), 143 (9.0%) Great Basin pocket mice (*Perognathus parvus*), 97 (6.1%) house mice (*Mus musculus*), 65 (4.1%) Merriam's shrews (*Sorex merriami*), 26 (1.6%) montane voles (*Microtus montanus*), 17 (1.1%) western harvest mice (*Reithrodontomys megalotis*), and 11 (0.7%) Ord's kangaroo rats (*Dipodomys ordii*).

Differences in small mammal species richness were detected among plantation ages during all trapping seasons, except summer 1997 and winter 1999. Species richness was always greater ($P < 0.021$) in 2-yr-old plantations when compared to 4- to 6-yr-old plantations, and was greater ($P < 0.012$) than 3-yr-old plantations during fall and winter 1998 (Tables 1, 2). Species richness in

TABLE 1. Mean species richness and small mammal captures per 100 trap nights on hybrid poplar plantations, 1997-1998. Means within a row followed by the same letter are not significantly different.

	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6
			Plantation Age			
			Spring 1997			
No. of species	1.0[a,b,c]	1.8[a]	1.5[a,b]	0.8[b,c]	0.3[c]	0.2[c]
No. of individuals	8.2[b]	17.5[a]	9.3[b]	1.0[c]	1.0[c]	0.2[c]
Deer mouse	2.5	8.7	6.8	0.5	0.5	0.2
Pocket mouse	5.7	2.7	1.3	0.2	0.0	0.0
House mouse	0.0	5.8	0.3	0.0	0.0	0.0
Harvest mouse	0.0	0.2	0.8	0.0	0.0	0.0
Montane vole	0.0	0.0	0.0	0.2	0.5	0.0
Kangaroo rat	0.0	0.2	0.0	0.0	0.0	0.0
Merriam's shrew	0.0	0.0	0.0	0.2	0.0	0.0
			Summer 1997			
No. of species	1.0[a]	1.5[a]	1.5[a]	0.7[a]	0.8[a]	0.5[a]
No. of individuals	2.5[b]	10.8[a]	11.2[a]	0.8[b]	3.5[b]	0.5[b]
Deer mouse	1.3	5.7	8.8	0.5	2.3	0.3
Pocket mouse	1.0	3.2	0.3	0.0	0.0	0.0
House mouse	0.2	1.8	0.8	0.0	0.0	0.0
Montane vole	0.0	0.0	0.7	0.0	0.7	0.0
Merriam's shrew	0.0	0.0	0.0	0.3	0.5	0.2
Harvest mouse	0.0	0.0	0.7	0.0	0.0	0.0
Kangaroo rat	0.0	0.2	0.0	0.0	0.0	0.0
			Fall 1997			
No. of species	0.7[a,b,c]	1.3[a]	0.8[a,b]	0.0[c]	0.3[b,c]	0.0[c]
No. of individuals	2.5[b]	8.0[a]	1.2[b]	0.0[b]	0.8[b]	0.0[b]
Deer mouse	1.3	6.2	0.5	0.0	0.0	0.0
Pocket mouse	1.2	1.3	0.0	0.0	0.0	0.0
Merriam's shrew	0.0	0.0	0.5	0.0	0.7	0.0
Montane vole	0.0	0.0	0.2	0.0	0.2	0.0
House mouse	0.0	0.3	0.0	0.0	0.0	0.0
Harvest mouse	0.0	0.2	0.0	0.0	0.0	0.0
			Winter 1998			
No. of species	1.3[a]	0.7[b]	0.2[c]	0.0[c]	0.2[c]	0.0[c]
No. of individuals	17.3[a]	16.8[a]	0.2[b]	0.0[b]	0.8[b]	0.0[b]
Deer mouse	16.5	16.5	0.0	0.0	0.0	0.0
Merriam's shrew	0.0	0.0	0.2	0.0	0.8	0.0
Harvest mouse	0.3	0.3	0.0	0.0	0.0	0.0
Pocket mouse	0.3	0.0	0.0	0.0	0.0	0.0
House mouse	0.2	0.0	0.0	0.0	0.0	0.0

1-yr-old plantations was greater ($P = 0.012$) than 3- to 6-yr-old plantations during fall 1998, and was greater ($P < 0.001$) than all other plantation ages during winter 1998 (Tables 1, 2). Species richness was greater ($P = 0.012$) in 3-yr-old plantations compared to 4- to 6-yr-old plantations during summer 1998, was greater ($P = 0.013$) than 5- and 6-yr-old plantations during spring 1997, and was greater ($P = 0.015$) than 4- and 6-yr-old plantations during fall 1997 (Tables 1, 2). Species richness was similar among 4- to 6-yr-old plantations during all seasons except spring 1998, when 6-yr-old plantations exceeded ($P = 0.021$) 4-yr-old plantations (Tables 1, 2).

Combined small mammal abundance differed among plantation ages during all trapping seasons except fall 1998. Total density was always greater ($P < 0.017$) in 2-yr-old plantations when compared to 4- to 6-yr-old plantations, was greater ($P < 0.017$) than 3-yr-old plantations during all seasons except summer 1997, and was greater ($P < 0.017$) than 1-yr-old plantations during all seasons

TABLE 2. Mean species richness and small mammal captures per 100 trap nights on hybrid poplar plantations, 1998-1999. Means within a row followed by the same letter are not significantly different.

	Plantation Age					
	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6
			Spring 1998			
No. of species	1.0[a,b,c]	1.7[a,b]	1.0[a,b,c]	0.3[a,b]	0.5[b,c]	1.2[a,b]
No. of individuals	8.8[b,c]	33.5[a]	13.2[b]	0.5[c]	1.2[c]	1.7[c]
Deer mouse	7.2	29.8	10.7	0.0	0.2	0.5
Pocket mouse	1.6	2.0	2.5	0.0	0.0	0.2
Merriam's shrew	0.0	0.0	0.0	0.3	1.0	0.8
House mouse	0.0	1.3	0.0	0.0	0.0	0.0
Montane vole	0.0	0.2	0.0	0.0	0.0	0.2
Harvest mouse	0.0	0.0	0.0	0.2	0.0	0.0
Kangaroo rat	0.0	0.2	0.0	0.0	0.0	0.0
			Summer 1998			
No. of species	1.0[a,b]	1.2[a]	1.2[a]	0.7[b,c]	0.3[c]	0.7[b,c]
No. of individuals	7.3[b,c]	17.3[a]	11.5[b]	1.7[c]	2.0[c]	4.7[c]
Deer mouse	6.5	16.0	10.5	1.5	0.8	3.2
House mouse	0.8	0.8	0.7	0.0	0.0	0.0
Merriam's shrew	0.0	0.0	0.3	0.0	1.2	0.3
Montane vole	0.0	0.2	0.0	0.0	0.0	1.2
Kangaroo rat	0.0	0.3	0.0	0.0	0.0	0.0
Harvest mouse	0.0	0.0	0.0	0.2	0.0	0.0
			Fall 1998			
No. of species	1.3[a]	1.3[a]	0.3[b]	0.3[b]	0.3[b]	0.3[b]
No. of individuals	7.5[a]	14.3[a]	1.8[a]	0.5[a]	0.2[a]	0.8[a]
Deer mouse	5.7	12.2	1.8	0.3	0.3	0.8
House mouse	1.3	1.5	0.0	0.0	0.0	0.0
Kangaroo rat	0.5	0.2	0.0	0.0	0.0	0.0
Montane vole	0.0	0.3	0.0	0.0	0.0	0.0
Merriam's shrew	0.0	0.0	0.0	0.2	0.0	0.0
Pocket mouse	0.0	0.2	0.0	0.0	0.0	0.0
			Winter 1999			
No. of species	1.0[a]	0.7[a]	0.3[a]	0.5[a]	0.5[a]	0.2[a]
No. of individuals	13.5[a]	4.8[b]	0.3[d]	2.8[c]	0.5[d]	0.2[d]
Deer mouse	13.0	4.5	0.0	0.0	0.3	0.2
Merriam's shrew	0.0	0.3	0.0	2.8	0.2	0.0
Pocket mouse	0.2	0.0	0.2	0.0	0.0	0.0
Kangaroo rat	0.3	0.0	0.0	0.0	0.0	0.0
House mouse	0.0	0.0	0.2	0.0	0.0	0.0

except winter 1998 (Tables 1, 2). Small mammal density was greater ($P < 0.017$) in 3-yr-old plantations compared to 4- to 6-yr-old plantations during spring and summer, and was similar during fall and winter (Tables 1, 2). Small mammal density was greater ($P < 0.009$) in 1-yr-old plantations compared to 4- to 6-yr-old plantations during spring 1997 and winter seasons. Total density was similar in 4- to 6-yr-old plantations for all seasons except winter 1999, when the density in 4-yr-old plantations exceeded ($P < 0.001$) 5- and 6-yr-old plantations (Tables 1, 2).

The deer mouse was the most abundant species captured in all plantation age classes combined (Tables 1, 2). The smallest effect was during fall 1997, when deer mouse captures outnumbered the pocket mouse by 3.3 times and the house mouse by 27 times ($P = 0.006$). The largest effect was during winter 1998 when the deer mouse was captured at a rate of 110 times greater ($P < 0.001$) than both the house mouse and pocket mouse. Densities for the pocket mouse and house mouse were similar during all trapping periods.

An interaction between plantation age and species abundance was detected ($P < 0.019$) during all trapping seasons except spring 1997 (Figure 1). Deer mouse densities typically peaked in 2-yr-old plantations and declined to near zero by age four. However, during winter 1999 the peak was in yr 1, in summer in yr 3 and in winter 1998 in yr 1 and 2. Pocket mouse and house mouse

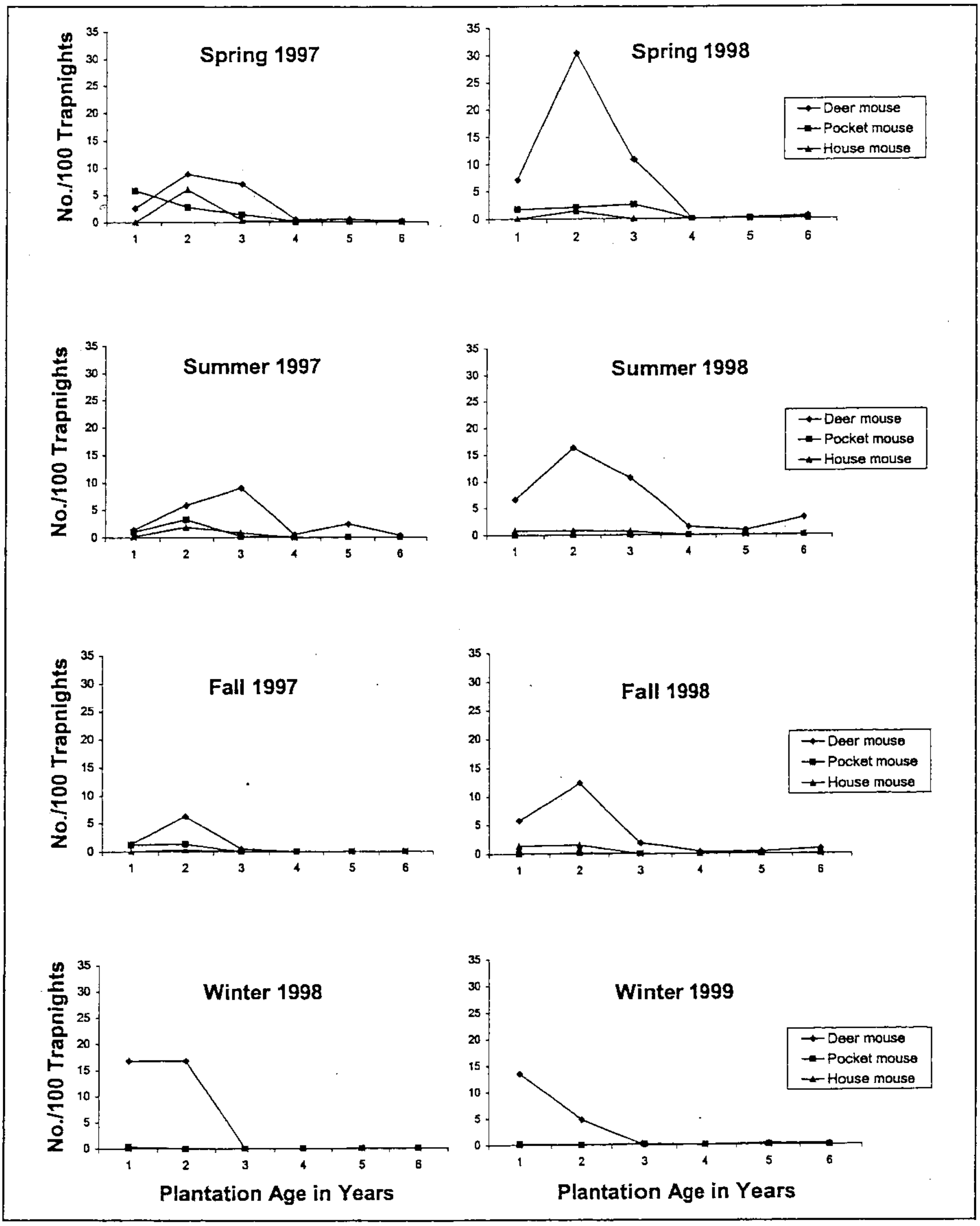

Figure 1. Change in rodent species abundance (number individuals per 100 trap nights) relative to stand age, spring 1997 through winter 1999.

densities peaked in 1- to 3-yr-old plantations, although the effects were not as large as for the deer mouse. Pocket mouse and house mouse densities declined to near zero by age four.

Discussion

High abundance and species richness of small mammals in young plantations were probably a result of abundant understory vegetation that provided both food and cover. Once plantations reached their fourth growing season, canopies closed and their floors were practically devoid of live plants, with abundant decomposing hybrid poplar leaves. Dyer et al. (1990) also reported that small mammal density was greatest in the youngest of short-rotation eucalyptus (*Eucalyptus camadulensis*) and casuarinas (*Casuarina cunninghamiana*) plantations in California, and gradually declined as the plantations aged. Total mammal densities were dominated by the deer mouse, which made up 77.5% of the total captures. The majority of captures in hybrid poplar plantations in the Midwest comprised habitat generalists, such as the deer mouse (Christian et al. 1997).

The only species captured consistently in the older plantations was Merriam's shrew, a species commonly associated with shrub-steppe (Hudson and Bacon 1956) and forest (Hoffmeister 1956). Thus, it was not surprising to find this species in the plantations, however, the insectivorous Merriam's shrews were captured only in the 3- to 6-yr-old plantations where the heavy leaf litter was abundant with attendant invertebrates such as worms and insect larvae. These small shrews were commonly observed moving below the leaf litter, which presumably provided cover from predators. The deer mouse commonly travels above this litter and is more susceptible to predation when herbaceous and woody cover is absent. Our results differed from Christian et al. (1997), who consistently captured other *Sorex* spp. in the young plantations that they studied.

A significant interaction between plantation age and species abundance demonstrated that species composition changed as plantations aged. The deer mouse was most abundant in 2-yr-old plantations, when vegetation control resulted in an early seral plant community preferred by the deer mouse (Borrecco et al. 1979). As plantations developed and the understory became less abundant, deer mouse numbers declined.

The pocket mouse was common in 1- to 3-yr-old plantations. Few were caught in winter, probably because the pocket mouse is torpid for > 90% of the winter months in this region (O'Farrell et al. 1975). The presence of the pocket mouse was most likely an artifact from the former shrub-steppe community and adjacent shrub-steppe areas. In addition, individuals might have immigrated into plantations from adjacent shrub-steppe. Verts and Carraway (1998) reviewed studies of the pocket mouse in Oregon and found it was most commonly associated with sandy soils in arid regions, dominated by shrub-steppe habitat. But the pocket mouse was also found in juniper woodlands in Oregon, which are structurally similar to shrub-steppe. Once our plantations reached 4-yr-old, the pocket mouse no longer inhabited them.

The house mouse was commonly captured in 1- to 3-yr-old plantations, but rarely in plantations > 4-yr-old. Again, lack of understory vegetation in older plantations created a hostile environment. True feral house mouse populations have not been reported previously in Oregon. Most of our plantations were > 0.8 km from human structures, suggesting young hybrid poplar plantations support feral populations. Dyer et al. (1990) also reported use of short-rotation plantations by the house mouse in California. Regardless of whether the house mouse dispersed from fabricated structures or persisted due to favorable habitat conditions, this mouse is an exotic species that may compete with native species or cause other adverse ecological consequences (Witmer and Lewis 2001).

Other species were low in abundance. The montane vole was captured in 2- to 6-yr-old plantations, and most of the sites within plantations where voles were caught had understory covers > 80% (even in the old plantations). Small patches of ground cover occur in old poplar plantations and provide refugia for small mammals in an otherwise inhospitable environment (Christian et al. 1998). The montane vole is economically important because it can cause irreparable damage to poplars by feeding on their bark and cambium (Moser and Witmer 2000). Vole populations can irrupt every 3-5 yr (Taitt and Krebs 1985), with high potential for tree damage. Another species captured only in plantations with higher-than-usual cover was the western harvest mouse. This species was captured in 1- to 4-yr-old plantations. Ord's kangaroo rat, a species commonly found only in shrub-steppe, was captured only in 1- and 2-yr-old plantations. This species was probably an artifact of the original shrub-steppe (Rogers and Hedlund 1980). In addition, individuals might have immigrated into plantations from adjacent shrub-steppe.

Our study suggests that young hybrid poplar plantations that have not achieved canopy closure may contain relatively abundant and diverse populations of small mammals compared to older plantations. In addition, replacement of native shrub-steppe habitats with hybrid poplar plantations may still provide habitat for the first 3 yr for some small mammal species thought to be dependent on shrub-steppe habitats.

Although this study addressed large, commercial plantations, smaller plantings used as conservation plantings, windrows, and phytoremediation projects may contain higher densities of small mammals due to the increased edge effect. Because small mammals play an important role in ecological processes, including nutrient cycling, seed dispersal, herbivory, and predator-prey dynamics (Chew 1976, French et al. 1976, Potter 1976), it is important that land managers consider this faunal group when designing plantings.

Establishment of within-plantation heterogeneity by creating openings or planting different aged trees would further increase the suitability of these plantations for wildlife populations (Hanowski et al. 1997), including small mammals. However, designing plantations to increase biodiversity may reduce fiber yield and lead to an increase in densities of economically important species such as voles (*Microtus* spp.). Due to the potential of voles to cause severe damage to plantations (Moser and Witmer 2000), and the loss of fiber yield that results from such damage, it is likely that successfully managing hybrid poplar plantations for biodiversity by increasing within-plantation heterogeneity will remain a challenge for managers. If biodiversity is an important consideration when designing plantation landscapes, creating heterogeneity by maintaining a diversity of plantation ages within the complex may help ensure that the greatest diversity of small mammal species will occupy these landscapes.

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Literature Cited

Borrecco, J. E., H. C. Black, and E. F. Hooven. 1979. Response of small mammals to herbicide-induced habitat changes. Northwest Science 53:97-106.

Chew, R. M. 1976. The impact of small mammals on ecosystem structure and function. Pages 167-180 *In* D. P. Snyder (editor), Populations of small mammals under natural conditions, University of Pittsburgh, Pymatuning Laboratory of Ecology, Pittsburgh, Pennsylvania.

Christian, D. P, P. T. Collins, J. M. Hanowski, and G. J. Niemi. 1997. Bird and small mammal use of short-rotation hybrid poplar plantations. Journal of Wildlife Management 61:171-182.

Christian, D. P., W. Hoffman, J. M. Hanowski, G. J. Niemi, and J. Beyea. 1998. Bird and mammal diversity on woody biomass plantations in North America. Biomass and Bioenergy 14:395-402.

Dyer, A. R., T. D. Kelly, and D. L. Chesemore. 1990. Distribution and abundance of rodents in agroforestry plantations in the San Joaquin Valley, California. Transactions of the Western Section of The Wildlife Society 26:91-96.

Edge, W. D. 2001. Wildlife of agriculture, pastures, and mixed environs. Pages 342-360 *In* D. H. Johnson and T. A. O'Neil (editors), Wildlife-habitat relationships in Oregon and Washington, Oregon State University Press, Corvallis, Oregon.

Franklin, J. F., and C. T. Dyrness. 1988. Natural vegetation of Oregon and Washington. Oregon State University Press, Corvallis, Oregon.

French, N. R., W. E. Grant, W. Grodzinski, and D. M. Swift. 1976. Small mammal energetics in grassland ecosystems. Ecological Monographs 46:201-220

Graham, R. L. 1994. An analysis of the potential land base for energy crops in the coterminous United States. Biomass and Bioenergy 6:175-189.

Hanowski, J. M., G. J. Niemi, and D. C. Christian. 1997. Influence of within-plantation heterogeneity and surrounding landscape composition on avian communities in hybrid poplar plantations. Conservation Biology 11:936-944.

Heilman, P. E., R. F. Stettler, D. P. Hanley, and R. W. Carkner. 1995. High yield hybrid poplar plantations in the Pacific Northwest. PNW Extension Bulletin No. 356. Washington State University Cooperative Extension, Pullman, Washington.

Hoffmeister, D. F. 1956. A record of *Sorex merriami* from northeastern Colorado. Journal of Mammalogy 37:276.

Hudson, G. E., and M. Bacon. 1956. New records of *Sorex merriami* for eastern Washington. Journal of Mammalogy 37:436-438.

Isebrands, J. G. 2000. Activities related to poplar and willow cultivation and utilization for the period 1996-2000: National Poplar Commission of the USA. Unpublished report on file with the International Poplar Commission, Rome, Italy.

Littell, R. C., G. A. Milliken, W. W. Stroup, and R. D. Wolfinger. 1996. SAS system for mixed models. SAS Institute Inc., Cary, North Carolina.

Moser, B. W., and G. W. Witmer. 2000. An integrated approach to wildlife damage management in hybrid poplar plantations. Pages 87-91 *In* K. A. Blatner, J. D. Johnson, and D. M. Baumgartner (editors), Hybrid poplars in the Pacific Northwest: culture, commerce, and capability, Cooperative Extension Service, Washington State University, Pullman, Washington.

O'Farrell, T. P., R. J. Olson, R. O. Gilbert, and J. D. Hedlund. 1975. A population of Great Basin pocket mice, *Perognathus parvus*, in the shrub-steppe of south-central Washington. Ecological Monographs 45:1-28.

Paine, L. K., T. L. Peterson, D. J. Undersander, K. C. Rineer, G. A. Bartelt, S. A. Temple, D. W. Sample, and R. M. Klemme. 1996. Some ecological and socio-economic considerations for biomass energy crop production. Biomass and Bioenergy 10:231-242.

Potter, G. L. 1976. The effect of small mammals on forest ecosystem structure and function. Pages 181-187 *In* D. P. Snyder (editor), Populations of small mammals under natural conditions, University of Pittsburgh, Pymatuning Laboratory of Ecology, Pittsburgh, Pennsylvania.

Rogers, L. E., and J. D. Hedlund. 1980. A comparison of small mammal populations occupying three distinct shrub-steppe communities in eastern Oregon. Northwest Science 54:183-186.

Ruffner, J. A. 1978. Climates of the United States. Volume 2. Gale Research Company, Detroit, Michigan.

SAS Institute Inc. 1996. SAS/STAT software: changes and enhancements through Release 6.11. Cary, North Carolina.

Taitt, M. J., and C. J. Krebs. 1985. Population dynamics and cycles. Pages 567-620 *In* R. H. Tamarin (editor), Biology of New World *Microtus*. American Society of Mammalogists Special Publication Number 8.

Verts, B. J., and L. N. Carraway. 1998. Land mammals of Oregon. University of California Press, Berkeley, California.

White, G. C., D. R. Anderson, D. P. Burnham, and D. L. Otis. 1982. Capture-recapture and removal methods for sampling closed populations. LA-8787-NERP, UC-11. Los Alamos National Laboratory, Los Alamos, New Mexico.

Witmer, G. G., and J. C. Lewis. 2001. Introduced wildlife of Oregon and Washington. Pages 423-443 *In* D. H. Johnson and T. A. O'Neil (editors), Wildlife-habitat relationships in Oregon and Washington, Oregon State University Press, Corvallis, Oregon.

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